

FORM PTO-1700
(REV. 10-98)

U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

ATTORNEY'S DOCKET NUMBER

TRANSMITTAL LETTER TO THE UNITED STATES
DESIGNATED/ELECTED OFFICE (DO/EO/US)
CONCERNING A FILING UNDER 35 U.S.C. 371

00336/TH

U.S. APPLICATION NO. (If known, see 37 CFR 1.51)

09/554629

INTERNATIONAL APPLICATION NO.

PCT/JP98/05212

INTERNATIONAL FILING DATE

19 November 1998

PRIORITY DATE CLAIMED 2 February

19 November 1997 & 1998

TITLE OF INVENTION

DEVICE FOR HOLDING SEMICONDUCTOR WAFER

APPLICANT(S) FOR DO/EO/US

Shinji NAKAHARA, Masato IMAI, Masanori MAYUSUMI and Kazutoshi INOUE

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. ☐ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
 - a. ☐ is transmitted herewith (required only if not transmitted by the International Bureau).
 - b. ☒ has been transmitted by the International Bureau.
 - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. ☐ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
 - a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
 - b. ☐ have been transmitted by the International Bureau.
 - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
 - d. ☐ have not been made and will not be made.
8. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☐ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. ☐ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 16. below concern document(s) or information included:

11. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☒ A **FIRST** preliminary amendment.
☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
14. ☐ A substitute specification.
15. ☐ A change of power of attorney and/or address letter.
16. ☒ Other items or information:
4 sheets formal drawings (Figs. 1-8)
Form PCT/IPEA, 416, 409 (IPE Report with annexes)

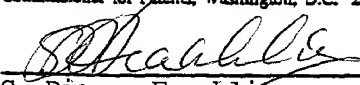
Express Mail Mailing Label No.:

EIL 484 825 972 US

Date of Deposit:

May 16, 2000

I hereby certify that this paper and any papers identified herein is being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 CFR 1.10 on the date indicated above and is addressed to the Assistant Commissioner for Patents, Washington, D.C. 20231


S. Dianne Franklin

17. ☒ The following fees are submitted:

BASIC NATIONAL FEE (37 CFR 1.492 (a) (1)-(5)):

Search Report has been prepared by the EPO or JPO \$840.00

International preliminary examination fee paid to USPTO (37 CFR 1.482) \$670.00

No international preliminary examination fee paid to USPTO (37 CFR 1.482) but international search fee paid to USPTO (37 CFR 1.445(a)(2)) \$760.00

Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO \$970.00

International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4) \$ 96.00

ENTER APPROPRIATE BASIC FEE AMOUNT =

\$ 840.00

Surcharge of \$130.00 for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(e)).

\$

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE
Total claims	8 - 20 =	0	\$ 18.00
Independent claims	2 - 3 =	0	\$ 78.00

MULTIPLE DEPENDENT CLAIM(S) (if applicable)

+ 260.00

\$

TOTAL OF ABOVE CALCULATIONS =

\$ 840.00

Reduction of 1/2 for filing by small entity, if applicable. Verified Small Entity Statement must also be filed (Note 37 CFR 1.9, 1.27, 1.28).

\$

SUBTOTAL =

\$ 840.00

Processing fee of \$130.00 for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(f)).

\$

TOTAL NATIONAL FEE =

\$ 840.00

Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). \$40.00 per property

\$

TOTAL FEES ENCLOSED =

\$ 840.00

Amount to be:
refunded

\$

charged

\$

I ☒ A check in the amount of \$ 840.00 to cover the above fees is enclosed.I ☐ Please charge my Deposit Account No. _____ in the amount of \$ _____ to cover the above fees. A duplicate copy of this sheet is enclosed.I ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 06-1378. A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

FRISHAUF, HOLTZ, GOODMAN, LANGER & CHICK, P.C.
767 Third Avenue - 25th Floor
New York, NY 10017-2023

Tel. No. (212) 319-4900

Fax No. (212) 319-5101

Date: May 16, 2000

SIGNATURE

Leonard Holtz

NAME

22,974

REGISTRATION NUMBER

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Application No. :

U.S. National Serial No. :

PCT International Application No. : PCT/JP98/05212

VERIFICATION OF A TRANSLATION

I, the undersigned translator, hereby declare that :


My name and post office address are as stated below;

That I am knowledgeable in the Japanese language in which the below identified international application was filed, and that I believe the English translation of the international application No. PCT/JP98/05212 is a true and complete translation of the above identified international application as filed.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that wilful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such wilful false statements may jeopardize the validity of the application or any patent issued thereon.

Dated this 8th day of May, 2000, at Tokyo, Japan

Full name of the translator :



Gen OGAWA

Post Office Address :

SANWA INTERNATIONAL PATENT OFFICE,
Syuwa No. 2 Toranomon Bldg.,
21-19, Toranomon 1-chome, Minato-ku, Tokyo,
105-0001 JAPAN

09/554629

422 Rec'd PCT/PTO 16 MAY 2000

Attorney Docket No. 00336/LH

**IN THE UNITED STATES PATENT
AND TRADEMARK OFFICE**

Applicant(s): Shinji NAKAHARA
Masato IMAI
Masanori MAYASUMI
Kazutoshi INOUE

Serial No. : To be assigned (U.S.
National Phase of
PCT/JP98/05212, filed
November 11, 1998)

Filed : Concurrently herewith

For : DEVICE FOR HOLDING
SEMICONDUCTOR WAFER

Art Unit :

Examiner :

Express Mail Mailing Label

No.: EL 484 825 972 US

Date of Deposit: May 16, 2000

I hereby certify that this paper is
being deposited with the United States
Postal Service "Express Mail Post Office
to Addressee" service under 37 CFR 1.10
on the date indicated above and is
addressed to the Assistant Commissioner
for Patents, Washington, D.C. 20231


St. Dianne Franklin

In the event that this Paper is late
filed, and the necessary petition for
extension of time is not filed
concurrently herewith, please consider
this as a Petition for the requisite
extension of time, and to the extent not
tendered by check attached hereto,
authorization to charge the extension
fee, or any other fee
required in connection with this Paper
to Account No. 06-1378.

PRELIMINARY AMENDMENT

Attention: BOX PCT
Assistant Commissioner for Patents
Washington, D.C. 20231

S I R :

Please amend the above-identified application as follows:

IN THE SPECIFICATION:

Page 9, line 29, change "exerting a holding force of" to
--being adapted to act against said
peripheral edge of said wafer to exert a
holding force toward the center of said
wafer in--.

Page 10, line 5, after "the" (second occurrence) insert
--force of--;

lines 7-10, delete in their entirety and substitute therefor --instance, this can be achieved by exerting the actuating force tending toward the center of the wafer upon the wafer peripheral edge.--.

Page 14, line 17, after "invention," insert --there is provided a wafer holding device adapted for use in an apparatus for treating a principal surface of a semiconductor wafer under a predetermined heating condition while the back surface of said principal surface of the wafer is vertically or obliquely held by the device at the predetermined position within a chamber of said apparatus. The device comprises a substrate holder for supporting the back surface of said wafer thereon and rotating means for circumferentially rotating said wafer along with the substrate holder.--;

line 18, change "the" to --The--.

IN THE CLAIMS:

Please amend claim 5 as follows:

5. (Amended) A wafer holding device adapted for use in an apparatus for treating a principal surface of a semiconductor wafer under a predetermined heating condition while the back surface of said principal surface of the wafer is vertically or

5 obliquely held by the device at a predetermined position within a chamber of said apparatus, said device comprising:

a substrate holder for supporting the back surface of said wafer thereon,

10 a rotating means for circumferentially rotating said wafer along with the substrate holder, and

a plurality of holding members provided on said substrate holder and [adapted to] placed in contact with [a] the peripheral edge of said wafer loaded [on said substrate holder] thereon, said holding members [exerting a holding force of] being adapted to act against said peripheral edge of said wafer to exert a holding force toward the center of said wafer in such degree that said wafer is prevented from coming off when said wafer is rotated along said substrate holder by said rotating means.

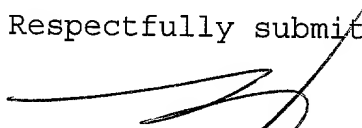
REMARKS

The specification and claims have been amended as set forth in the PCT Amendment under Article 34 filed on November 12, 1999 during the PCT proceedings. An English translation of the amended replacement pages filed with said Article 34 Amendment filed November 12, 1999 is enclosed herewith.

No new matter has been added. It is respectfully requested that the amendments to the specification and claims be approved and entered. It is further respectfully requested that prosecution on the merits now proceed on the basis of the application as set forth hereinabove.

If the Examiner has any comments, questions, objections or recommendations, the Examiner is invited to telephone the undersigned at the telephone number given below for prompt action.

Respectfully submitted,


Leonard Holtz, Esq.
Reg. No. 22,974

Dated: May 16, 2000

Frishauf, Holtz, Goodman, Langer & Chick, P.C.
767 Third Avenue - 25th Floor
New York, New York 10017-2023
Tel. No. (212) 319-4900
Fax No. (212) 319-5101
LH/sdf
sdf/c:\d:\00\00336.pre

DEVICE FOR HOLDING SEMICONDUCTOR WAFER

Technical Field

The present invention relates to a device for holding a semiconductor wafer and more particularly to a wafer holding device which is well suited for application to apparatus for performing a heat treatment on semiconductor wafers.

Background Art

In the process of semiconductor wafer fabrication, various heat treatments are performed on semiconductor wafers. Included among such heat treatments are mainly the formation of oxide films, the epitaxial growth by chemical vapor deposition (CVD) process, the dopant diffusion process and the gettering heat treatment. In the apparatus for effecting the heat treatment on semiconductor wafers, a semiconductor wafer is first placed on a substrate holder such as a board or susceptor disposed in a given position within a heat treatment furnace e.g., oxidation furnace or epitaxial growth furnace. Then, the required gas is introduced into the furnace and the wafer is heated to 1000 °C or over in the gaseous atmosphere, thereby performing the heat treatment corresponding to the process.

For instance, in the case of the silicon epitaxial growth process by the H-Si-Cl type CVD process, generally the following steps are performed. The wafer is loaded on an SiC-CVD susceptor (usually a graphite material subjected to a CVD coating with SiC) within the chamber which is heated by a radiation type heater and a silicon source gas of SiCl_4 , SiHCl_3 , SiH_2Cl_2 , SiH_4 or the like is supplied by means of a hydrogen carrier. Thus, an epitaxial film is grown on the wafer through an H-Si-Cl type reaction.

Where the wafer is horizontally loaded on the susceptor and a heat treatment e.g., an epitaxial growth process is effected, the outer peripheral surface on the back side of the wafer is brought into substantially uniform contact

with the susceptor. In fact, however, the surface of the commonly used SiC-CVD type susceptor has a limit to the degree of smoothness due to its manufacturing process and it is a rough surface. This rough surface involves a large number of irregular projections on the susceptor surface and these projections support the wafer from the back side in a point contact manner.

Thus, in the conventional apparatus, the wafer is supported by the plurality of nonuniform projections with the result that the back side of the wafer is loaded locally. Particularly, where the projections contact with the semiconductor wafer at its weak portions from the physical property point of view, the wafer undergoes stress so that under the high temperature environment during the performance of the epitaxial growth process there is the danger of causing a so-called slip defect which in turn causes the crystal to suffer a slip deformation with the resulting occurrence of minute irregularities on the wafer surface.

Particularly and recently, in the case of large-diameter semiconductor wafers of 400 mm or over in diameter, the weight of the wafer itself has the effect of increasing the local loading acting on the points of contact of the wafer with the projections and thus the problem of stress on the wafer is no longer ignorable.

On the other hand, apparatus of vertical type have been known in which a semiconductor wafer is held on a vertical or oblique susceptor and is subjected as such to the desired heat treatment. Such vertical-type apparatus for performing a heat treatment on a semiconductor wafer requires no wide space for installation thereof and is used in the case where the installation site for the apparatus is limited. Particularly, where a heat treatment is to be performed on semiconductor wafers of large diameters on the order of 400 mm in diameter which have recently been manufactured experimentally, the horizontal type apparatus requires an excessively large installation space than in the case of wafers of the ordinary size and thus it is desired that the heat treatment be effected by the vertical type apparatus. In such vertical type apparatus, a susceptor is formed with a recess (spot facing) for receiving a semiconductor

wafer and the wafer is received in the recess thereby holding it to prevent its dropping from the susceptor.

However, the conventional vertical type wafer heat treatment apparatus involves the following problems. That is, the semiconductor wafer is not always positively made fast in the recess of the susceptor. Thus, there is the danger of the wafer falling down or dropping from the susceptor during the performance of a heat treatment.

On the other hand, in the wafer heat treatment apparatus of the horizontal type as well as the single wafer processing type, the desired heat treatment is performed while rotating the wafer together with the susceptor in the circumferential direction so as to ensure uniform heat distribution and film formation distribution for the wafer on the susceptor. Also, in the case of the vertical type wafer heat treatment apparatus, the wafer must be rotated in the circumferential direction for the same reason as just mentioned. In the case of the vertical type apparatus, however, if the wafer is rotated together with the susceptor, the wafer is moved relative to and within the recess of the susceptor due to such external force as the gravity acting on the wafer. Thus, the wafer strikes against the inner wall surface of the recess or falls from the susceptor thereby causing flaws, cracks or the like on the wafer due to the impact shock of the collision or dropping. If the heat treatment is performed on the wafer having the resulting flaws, cracks or the like, crystal defects are caused and the quality of the semiconductor wafer is deteriorated.

In order to prevent this, it is conceivable to fixedly support the wafer within the recess of the susceptor or on the susceptor. In this case, however, there is the problem that the wafer suffers an excessive force through the supporting members due to such external force as the gravity acting on the wafer and thus flaws, cracks or the like are caused on the wafer. In addition, there are problems such as the occurrence in the wafer of crystal defects due to the distortion by thermal deformation. These are serious problems, particularly in the

case of large-diameter semiconductor wafers.

Disclosure of Invention

In view of the foregoing deficiencies, it is the primary object of the present invention to provide a device for holding a semiconductor wafer, which is capable of ensuring that a heat treatment is effected satisfactorily without causing a slip defect or the like in the wafer. Also, it is another object of the present invention to provide a device for holding a semiconductor wafer, which is capable of ensuring that where a heat treatment is performed on a semiconductor wafer while holding it in a vertical or inclined manner, the wafer is held positively to prevent it from falling down from a susceptor and thereby to enhance the quality of the semiconductor wafer. It is still another object of the present invention to provide a device for holding a semiconductor wafer, which is capable of ensuring that where a heat treatment is performed on a semiconductor wafer while holding it in a vertical or inclined manner, the heat treatment is performed while preventing the wafer from colliding due to its movement or dropping and rotating the wafer in the circumferential direction thereby producing the high-quality semiconductor wafer.

According to a first aspect of the present invention, there is provided a wafer holding device adapted for use in an apparatus for treating a principal surface of a semiconductor wafer under a predetermined heating condition while the back surface of said principal surface of the wafer is held by the device at a predetermined position within a chamber of said apparatus, said device comprising:

a susceptor formed in the surface thereof with a wafer loading area for supporting the back surface of the wafer, and

a plurality of support pins respectively disposed in four equiangularly spaced positions along the circumference of at least one concentric circle in said wafer loading area so as to protrude from said susceptor surface and support the

back surface of said wafer at the forward ends thereof and including a resilient mechanism, respectively.

In this invention, the semiconductor wafer is supported at at least four points protrusively disposed in the susceptor surface.

It is to be noted that, if an attempt is made to simply support with the four projections, in fact a three-point support results and eventually the local loading is increased at these supporting points, thereby increasing the stress in the semiconductor wafer.

In accordance with the present invention, however, the wafer is not only supported by the support pins arranged at the four equiangular intervals on the same circle, that is, at the angular intervals of 90 degrees in the circumferential direction, but also each of the support pins includes the resilient mechanism, and therefore the wafer can be supported uniformly by all of the support pins.

In other words, even when the wafer is first mounted on the susceptor so that the back surface of the wafer touches and contacts with the forward ends of the two or three support pins, these support pins are sunken by the resilient mechanism upon the addition of the weight of the wafer. As a result, the forward ends of all the support pins come into contact with the back surface of the wafer.

Each of the support pins reacts on the back surface of the wafer by the spring force of the resilient mechanism. Eventually, the loading of the wafer balances the spring force of the support pins and the wafer is supported uniformly and stably by the whole support pins. Thus, in accordance with the device of the present invention, the semiconductor wafer can be supported uniformly at the four points at the least so that as compared with the conventional device which inevitably provides only a three-point support, the stress caused in the semiconductor wafer will be reduced and a slip defect or the like will not be easily caused during the heat treatment such as epitaxial growth process.

According to a preferred embodiment of the present invention, said support pins are disposed in the positions which support the wafer along the

crystal orientation $\langle 110 \rangle$ with respect to the crystal plane (100) of the wafer.

According to another preferred embodiment of the present invention, said resilient mechanism includes a flexible member adapted for supporting the respective support pins.

In general, the semiconductor wafer is a silicon wafer substrate cut along the crystal plane (100). In this case, it has been known generally that in the surface the mechanical strength is highest at those positions along the crystal orientation $\langle 110 \rangle$ and the mechanical strength is lowest at the positions corresponding to the crystal orientations [001] and [010].

Assuming that the support pins of the device according to the present invention support along the crystal orientation $\langle 110 \rangle$ in the back surface of the semiconductor wafer, the wafer is supported at least at the four locations of the highest mechanical strength from the physical property point of view thereby supporting the wafer more stably. This is particularly advantageous in the case of those wafers which are great in weight and large in diameter.

It is to be noted that the crystal orientation $\langle 110 \rangle$ means the crystal orientation [110] and those which have the common properties from the crystal structural point of view and are thus equivalent to the former in the cubic system such as a silicon single crystal. More specifically, those shown in the following table 1 are meant.

Table 1

	Orientation
A	$[1\ 1\ 0]$
B	$[\bar{1}\ 1\ 0]$
C	$[1\ \bar{1}\ 0]$
D	$[\bar{1}\ \bar{1}\ 0]$
E	$[0\ 1\ 1]$
F	$[0\ \bar{1}\ 1]$
G	$[0\ 1\ \bar{1}]$
H	$[0\ \bar{1}\ \bar{1}]$
I	$[1\ 0\ 1]$
J	$[\bar{1}\ 0\ 1]$
K	$[1\ 0\ \bar{1}]$
L	$[\bar{1}\ 0\ \bar{1}]$

For instance, in the above Table 1 the crystal orientations designated respectively as E, F, G and H are the equivalent orientations to the crystal orientation $[110]$ and these orientations are not only lying in the radial directions of the semiconductor wafer but also spaced apart from one another by an equal angle of 90 degrees in the circumferential direction of the wafer. Thus, where the positions corresponding to any one of these four orientations on the wafer back surface are selected as the desired supporting positions by the support pins, by setting the other supporting positions to the other positions at angular intervals of 90 degrees on the susceptor, they can easily be made the corresponding positions along the previously mentioned orientations on the wafer back surface.

Also, the semiconductor wafer is usually provided with a marking such as an orientation flat or orientation notch indicating the $\langle 110 \rangle$ orientation in the principal surface of the wafer. Thus, by making use of such marking, it is

possible to easily effect the desired positioning on the susceptor in such a manner that the supporting positions on the wafer back surface of the selected support pins coincide with any one of the previously mentioned orientations E, F, G and H.

Also, it is needless to say that the local loading is reduced and the stress in the wafer is decreased with increase in the number of the support pins provided on the susceptor. In this case, it is only necessary to select as a basis an arrangement in which the support pins protrusively disposed at angular intervals of 90 degrees along the circumference of a plurality of concentric circles are at the positions corresponding to the four $\langle 110 \rangle$ orientations and are arranged radially within the wafer surface.

In accordance with a preferred embodiment of the present invention, the resilient mechanism includes a flexible member adapted for supporting the respective support pins.

In this case, since the flexible member is used as the resilient mechanism for the support pins, there is the effect of simplifying the construction. The reason is that even if the support pins themselves are of rigid nature, using the construction in which the support pins are supported by the flexible member has the effect of providing the respective support pins with a spring force.

The suitable materials for the flexible member include, for example, a quartz plate which bends slightly under an external force. More specifically, it is possible to construct so that the quartz plate is arranged on the lower surface side of the susceptor and the support pins protrusively disposed at the desired positions on the quartz plate are fitted through the susceptor to project from its surface. In another exemplary construction, recesses or blind holes are formed at the desired positions in the surface of the susceptor and projecting members serving as the support pins are respectively fitted in the holes with the backup leaf springs made from quartz.

Of course, in the present invention the resilient mechanism of the support

ART 34 AMDT

Translation of Japanese Substitute Page 8
(Amendment filed on November 12, 1999)

pins is not limited to the constructions using such quartz springs and any other constructions can be used satisfactorily provided that when holding a semiconductor wafer by a susceptor during the performance of the heat treatment such as an epitaxial growth process, support pins are made resilient so that the wafer can be supported uniformly and safely by all the support pins.

Thus, by virtue of the construction of the device according to the present invention in which a semiconductor wafer is supported by the support pins provided with the resilient mechanism, a uniform support at four or more positions can be attained. Therefore, as compared with the conventional cases of support using only three points, there is the effect of reducing the local loading at the supporting locations, reducing the stress in the wafer and greatly decreasing the danger of the occurrence of a slip during heat treatment of the wafer.

Further, by arranging the supporting positions of the support pins to lie along the crystal orientation $\langle 110 \rangle$ in the wafer cut along the crystal plane (100), the wafer is supported at the locations where the mechanical strength of the wafer is highest so that even if the wafer is large in diameter and weight, it can be supported stably with the reduced stress.

Also, in accordance with a second aspect of the present invention, there is provided a device for holding a semiconductor wafer, which is adapted for use in an apparatus for treating a principal surface of the wafer under a predetermined heating condition while the back surface of the principal surface of the wafer is vertically or obliquely held by the device at a predetermined position within a chamber of said apparatus, said device comprising:

- a substrate holder for supporting the back surface of said wafer thereon,
- rotating means for circumferentially rotating said wafer along with the substrate holder, and

- a plurality of holding members provided on said substrate holder and placed in contact with the peripheral edge of said wafer loaded thereon, said holding members being adapted to act against said peripheral edge of said wafer

to exert a holding force toward the center of said wafer in such degree that said wafer is not allowed to come off from its position even though the wafer is rotated along said substrate holder by said rotating means.

In the description of the present invention, the term "such degree that the wafer is not allowed to come off even though it is rotated" means that the wafer can be held in position by a force which opposes the external forces such as the force of the gravity acting on the wafer and the thermal stress, during its rotation. For instance, this can be achieved by exerting the actuating force tending toward the center of the wafer upon the wafer peripheral edge.

The holding members exerting such holding force may for example be composed of resilient members made from such material as a thin quartz, SiC or the like or members including such resilient members.

According to the second aspect of the present invention, since the holding members hold the wafer in position by causing a holding force opposing the external forces, etc., applied to the wafer to act on the peripheral edge of the wafer, the wafer can be held positively while being held in a vertical or inclined manner. Thus, during the performance of a heat treatment, the wafer can be prevented from falling down or dropping from the substrate holder. Also, when the wafer is rotated by the rotating means, the holding force by the holding members can oppose the external forces, e.g., the force of gravity acting on the wafer and the thermal stress, and therefore the wafer can be prevented from coming off or moving on the substrate holder. As a result, it is possible to avoid shock due to the dropping or the collision against any other member due to the movement and hence it is possible to produce the high-quality semiconductor wafer having no crystal defect caused therein.

According to a preferred embodiment of the present invention, the substrate holder includes holding members which contact with the peripheral edge of the wafer loaded on the holder and exert a holding force of such order

that the wafer is not allowed to come off even if it is rotated while being held vertically or obliquely at the desired position within the heat treatment apparatus.

In this case, if the substrate holder is installed in a vertical or oblique manner, the holding members prevent the wafer from falling down or dropping from the substrate holder. Also, even when the wafer is rotated, it is possible to prevent the dropping or movement of the wafer and thereby to prevent the occurrence of crystal defects in the wafer.

According to a preferred embodiment of the present invention, the substrate holder includes an inner wall surface facing the peripheral edge of the wafer loaded on the holder, and said holding members include contact members for contacting with the peripheral edge of the wafer and energizing members disposed on said inner wall surface for applying a force tending toward the center to the contact members.

In this case, the energizing members disposed on the inner wall surface of the substrate holder cause the energizing force tending toward the center to act on the contact members. This energizing force acts on the peripheral edge of the wafer through the contact members. As a result, the wafer can be positively held at its peripheral edge by the contact members and the energizing members of the holding members. Thus, the vertically or obliquely held state of the wafer can be maintained stably and the falling down of the wafer or its dropping from the substrate holder can be prevented. Also, even if the wafer is rotated by the rotating means, the external forces such as the force of gravity acting on the wafer is absorbed by the energizing force from the energizing members through the contact members, thereby preventing the wafer from coming off or dropping from the substrate holder or preventing the wafer from moving and colliding against the inner wall surface of the substrate holder. Accordingly, it is possible to prevent the occurrence of crystal defects by the shock due to the dropping or collision thereby producing the high-quality semiconductor wafer. Also, even if the wafer is thermally deformed, the contact members and the wafer are brought

into close contact positively by the energizing force thus maintaining the holding condition.

It is possible to use, for example, resilient members, e.g., springs made from such materials as thin quartz and SiC for the energizing members. As for the contact members, it is possible to use, for example, members made from such materials as carbon SiC-CVD coated material, SiC material, quartz, etc. Also, the energizing member and the contact member can be combined as a unit. In this case, there is the advantage of eliminating the need to separately prepare the two members and reducing the production cost of the apparatus.

According to another preferred embodiment of the present invention, the substrate holder includes an inner wall surface facing the peripheral edge of the wafer mounted thereon, and holding members for contacting with the peripheral edge of the mounted wafer and exerting a holding force of such degree that the wafer is not allowed to come off the holder even if the wafer is rotated while being held vertically or obliquely at the desired position within the heat treatment apparatus, and the holding members include contact members for contacting with the peripheral edge of the wafer and energizing members disposed on said inner wall surface to respectively apply an energizing force tending toward the center to the contact members.

In this case, where the substrate holder is held vertically or obliquely in position, the falling down or dropping of the wafer is prevented by the inner wall surface, the contact members and the energizing members. Also, even if the wafer is rotated, the dropping or movement of the wafer can be prevented thus avoiding the occurrence of crystal defects.

According to still another preferred embodiment of the present invention, the substrate holder includes an inner wall surface facing the peripheral edge of the wafer mounted thereon, and said holding members include inner-wall contact members composed of a part or the whole of the plurality of sections forming the inner wall surface, and energizing members for energizing the inner-wall contact

members toward the center.

In this case, the energizing members cause an energizing force tending toward the center to act on the inner-wall contact members composed of a part or the whole of the plurality of sections of the inner wall surface of the substrate holder. This energizing force acts on the peripheral edge of the wafer through the inner-wall contact members. In other words, an energizing force due to the surface contact of the inner-wall contact members acts on the peripheral edge of the wafer. Thus, in accordance with this embodiment the semiconductor wafer can be more positively held by the inner-wall contact members and the energizing members than in the case where an energizing force by a point contact acts on the wafer. As a result, the maintenance of the vertical or inclined state of the wafer is made more stable thus making it possible to prevent the falling down or the dropping of the wafer from the substrate holder. Further, even if the wafer is rotated by the rotating means, the external forces e.g., the force of gravity acting on the wafer is absorbed by the energizing force of the energizing members acting through the inner-wall contact members, thus making it possible to prevent the rotating wafer from coming off and dropping from the substrate holder or the movement of the wafer. Thus, it is possible to avoid the occurrence of crystal defects due to the shock by the dropping or collision and thereby to produce the high-quality semiconductor wafer. Also, even though the wafer undergoes a thermal deformation, the energizing force brings the inner-wall contact members and the wafer into close contact more positively thereby making possible the maintenance of the holding condition.

Resilient members such as springs made, for example, from the materials including thin quartz and SiC may be used for such energizing members.

Also, the wall surface of each recess provided in the substrate holder may be used as the inner-wall contact members.

Thus, in accordance with this embodiment the inner-wall contact members of the holding members constitute a part of the inner wall surface of the substrate

holder and therefore there is no need to produce the two members separately with the resulting reduction in the production cost of the apparatus.

According to still another preferred embodiment of the present invention, the substrate holder includes an inner wall surface facing the peripheral edge of the wafer mounted thereon, and holding members adapted to contact with the peripheral edge of the mounted wafer and exert a holding force of the order that the wafer is not allowed to come off even if it is rotated while being held vertically or obliquely at the desired position within the heat treatment apparatus, and said holding members include inner-wall contact members composed of a part or the whole of the plurality of sections of said inner wall surface, and energizing members for energizing said inner-wall contact members toward the center.

In this embodiment, where the substrate holder is held vertically or obliquely, the falling down or dropping of the wafer can be prevented by the inner-wall contact members and the energizing members. Also, even though the wafer is rotated, the occurrence of crystal defects due to the dropping or movement of the wafer can be prevented.

According to still another preferred embodiment of the present invention, there is provided a wafer holding device adapted for use in an apparatus for treating a principal surface of a semiconductor wafer under a predetermined heating condition while the back surface of said principal surface of the wafer is vertically or obliquely held by the device at a predetermined position within a chamber of said apparatus. The device comprises a substrate holder for supporting the back surface of said wafer thereon and rotating means for circumferentially rotating said wafer along with the substrate holder. The substrate holder includes a peripheral edge contact portion adapted for contacting with at least the back surface side of the peripheral edge of the mounted wafer, and the holding members include clamping members adapted for contacting with the principal surface side of the peripheral edge of the mounted wafer and for clamping and holding the wafer between the same and the peripheral edge

contact portion.

In this embodiment, the holding members include the clamping members adapted for contacting with the principal surface side of the peripheral edge of the mounted wafer and for clamping and holding the wafer between the same and the peripheral edge contact portion. As a result, clamping forces tending toward the inside act on the wafer from the principal surface side of the peripheral edge and the substrate holder side. By virtue of the clamping forces,

11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
100
101
102
103
104
105
106
107
108
109
110
111
112
113
114
115
116
117
118
119
120
121
122
123
124
125
126
127
128
129
130
131
132
133
134
135
136
137
138
139
140
141
142
143
144
145
146
147
148
149
150
151
152
153
154
155
156
157
158
159
160
161
162
163
164
165
166
167
168
169
170
171
172
173
174
175
176
177
178
179
180
181
182
183
184
185
186
187
188
189
190
191
192
193
194
195
196
197
198
199
200
201
202
203
204
205
206
207
208
209
210
211
212
213
214
215
216
217
218
219
220
221
222
223
224
225
226
227
228
229
230
231
232
233
234
235
236
237
238
239
240
241
242
243
244
245
246
247
248
249
250
251
252
253
254
255
256
257
258
259
260
261
262
263
264
265
266
267
268
269
270
271
272
273
274
275
276
277
278
279
280
281
282
283
284
285
286
287
288
289
290
291
292
293
294
295
296
297
298
299
300
301
302
303
304
305
306
307
308
309
310
311
312
313
314
315
316
317
318
319
320
321
322
323
324
325
326
327
328
329
330
331
332
333
334
335
336
337
338
339
340
341
342
343
344
345
346
347
348
349
350
351
352
353
354
355
356
357
358
359
360
361
362
363
364
365
366
367
368
369
370
371
372
373
374
375
376
377
378
379
380
381
382
383
384
385
386
387
388
389
390
391
392
393
394
395
396
397
398
399
400
401
402
403
404
405
406
407
408
409
410
411
412
413
414
415
416
417
418
419
420
421
422
423
424
425
426
427
428
429
430
431
432
433
434
435
436
437
438
439
440
441
442
443
444
445
446
447
448
449
450
451
452
453
454
455
456
457
458
459
460
461
462
463
464
465
466
467
468
469
470
471
472
473
474
475
476
477
478
479
480
481
482
483
484
485
486
487
488
489
490
491
492
493
494
495
496
497
498
499
500
501
502
503
504
505
506
507
508
509
510
511
512
513
514
515
516
517
518
519
520
521
522
523
524
525
526
527
528
529
530
531
532
533
534
535
536
537
538
539
540
541
542
543
544
545
546
547
548
549
550
551
552
553
554
555
556
557
558
559
560
561
562
563
564
565
566
567
568
569
570
571
572
573
574
575
576
577
578
579
580
581
582
583
584
585
586
587
588
589
590
591
592
593
594
595
596
597
598
599
600
601
602
603
604
605
606
607
608
609
610
611
612
613
614
615
616
617
618
619
620
621
622
623
624
625
626
627
628
629
630
631
632
633
634
635
636
637
638
639
640
641
642
643
644
645
646
647
648
649
650
651
652
653
654
655
656
657
658
659
660
661
662
663
664
665
666
667
668
669
670
671
672
673
674
675
676
677
678
679
680
681
682
683
684
685
686
687
688
689
690
691
692
693
694
695
696
697
698
699
700
701
702
703
704
705
706
707
708
709
710
711
712
713
714
715
716
717
718
719
720
721
722
723
724
725
726
727
728
729
730
731
732
733
734
735
736
737
738
739
740
741
742
743
744
745
746
747
748
749
750
751
752
753
754
755
756
757
758
759
760
761
762
763
764
765
766
767
768
769
770
771
772
773
774
775
776
777
778
779
780
781
782
783
784
785
786
787
788
789
790
791
792
793
794
795
796
797
798
799
800
801
802
803
804
805
806
807
808
809
810
811
812
813
814
815
816
817
818
819
820
821
822
823
824
825
826
827
828
829
830
831
832
833
834
835
836
837
838
839
840
841
842
843
844
845
846
847
848
849
850
851
852
853
854
855
856
857
858
859
860
861
862
863
864
865
866
867
868
869
870
871
872
873
874
875
876
877
878
879
880
881
882
883
884
885
886
887
888
889
890
891
892
893
894
895
896
897
898
899
900
901
902
903
904
905
906
907
908
909
910
911
912
913
914
915
916
917
918
919
920
921
922
923
924
925
926
927
928
929
930
931
932
933
934
935
936
937
938
939
940
941
942
943
944
945
946
947
948
949
950
951
952
953
954
955
956
957
958
959
960
961
962
963
964
965
966
967
968
969
970
971
972
973
974
975
976
977
978
979
980
981
982
983
984
985
986
987
988
989
990
991
992
993
994
995
996
997
998
999
1000
1001
1002
1003
1004
1005
1006
1007
1008
1009
1010
1011
1012
1013
1014
1015
1016
1017
1018
1019
1020
1021
1022
1023
1024
1025
1026
1027
1028
1029
1030
1031
1032
1033
1034
1035
1036
1037
1038
1039
1040
1041
1042
1043
1044
1045
1046
1047
1048
1049
1050
1051
1052
1053
1054
1055
1056
1057
1058
1059
1060
1061
1062
1063
1064
1065
1066
1067
1068
1069
1070
1071
1072
1073
1074
1075
1076
1077
1078
1079
1080
1081
1082
1083
1084
1085
1086
1087
1088
1089
1090
1091
1092
1093
1094
1095
1096
1097
1098
1099
1100
1101
1102
1103
1104
1105
1106
1107
1108
1109
1110
1111
1112
1113
1114
1115
1116
1117
1118
1119
1120
1121
1122
1123
1124
1125
1126
1127
1128
1129
1130
1131
1132
1133
1134
1135
1136
1137
1138
1139
1140
1141
1142
1143
1144
1145
1146
1147
1148
1149
1150
1151
1152
1153
1154
1155
1156
1157
1158
1159
1160
1161
1162
1163
1164
1165
1166
1167
1168
1169
1170
1171
1172
1173
1174
1175
1176
1177
1178
1179
1180
1181
1182
1183
1184
1185
1186
1187
1188
1189
1190
1191
1192
1193
1194
1195
1196
1197
1198
1199
1200
1201
1202
1203
1204
1205
1206
1207
1208
1209
1210
1211
1212
1213
1214
1215
1216
1217
1218
1219
1220
1221
1222
1223
1224
1225
1226
1227
1228
1229
1230
1231
1232
1233
1234
1235
1236
1237
1238
1239
1240
1241
1242
1243
1244
1245
1246
1247
1248
1249
1250
1251
1252
1253
1254
1255
1256
1257
1258
1259
1260
1261
1262
1263
1264
1265
1266
1267
1268
1269
1270
1271
1272
1273
1274
1275
1276
1277
1278
1279
1280
1281
1282
1283
1284
1285
1286
1287
1288
1289
1290
1291
1292
1293
1294
1295
1296
1297
1298
1299
1300
1301
1302
1303
1304
1305
1306
1307
1308
1309
1310
1311
1312
1313
1314
1315
1316
1317
1318
1319
1320
1321
1322
1323
1324
1325
1326
1327
1328
1329
1330
1331
1332
1333
1334
1335
1336
1337
1338
1339
1340
1341
1342
1343
1344
1345
1346
1347
1348
1349
1350
1351
1352
1353
1354
1355
1356
1357
1358
1359
1360
1361
1362
1363
1364
1365
1366
1367
1368
1369
1370
1371
1372
1373
1374
1375
1376
1377
1378
1379
1380
1381
1382
1383
1384
1385
1386
1387
1388
1389
1390
1391
1392
1393
1394
1395
1396
1397
1398
1399
1400
1401
1402
1403
1404
1405
1406
1407
1408
1409
1410
1411
1412
1413
1414
1415
1416
1417
1418
1419
1420
1421
1422
1423
1424
1425
1426
1427
1428
1429
1430
1431
1432
1433
1434
1435
1436
1437
1438
1439
1440
1441
1442
1443
1444
1445
1446
1447
1448
1449
1450
1451
1452
1453
1454
1455
1456
1457
1458
1459
1460
1461
1462
1463
1464
1465
1466
1467
1468
1469
1470
1471
1472
1473
1474
1475
1476
1477
1478
1479
1480
1481
1482
1483
1484
1485
1486
1487
1488
1489
1490
1491
1492
1493
1494
1495
1496
1497
1498
1499
1500
1501
1502
1503
1504
1505
1506
1507
1508
1509
1510
1511
1512
1513
1514
1515
1516
1517
1518
1519
1520
1521
1522
1523
1524
1525
1526
1527
1528
1529
1530
1531
1532
1533
1534
1535
1536
1537
1538
1539
1540
1541
1542
1543
1544
1545
1546
1547
1548
1549
1550
1551
1552
1553
1554
1555
1556
1557
1558
1559
1560
1561
1562
1563
1564
1565
1566
1567
1568
1569
1570
1571
1572
1573
1574
1575
1576
1577
1578
1579
1580
1581
1582
1583
1584
1585
1586
1587
1588
1589
1590
1591
1592
1593
1594
1595
1596
1597
1598
1599
1600
1601
1602
1603
1604
1605
1606
1607
1608
1609
1610
1611
1612
1613
1614
1615
1616
1617
1618
1619
1620
1621
1622
1623
1624
1625
1626
1627
1628
1629
1630
1631
1632
1633
1634
1635
1636
1637
1638
1639
1640
1641
1642
1643
1644
1645
1646
1647
1648
1649
1650
1651
1652
1653
1654
1655
1656
1657
1658
1659
1660
1661
1662
1663
1664
1665
1666
1667
1668
1669
1670
1671
1672
1673
1674
1675
1676
1677
1678
1679
1680
1681
1682
1683
1684
1685
1686
1687
1688
1689
1690
1691
1692
1693
1694
1695
1696
1697
1698
1699
1700
1701
1702
1703
1704
1705
1706
1707
1708
1709
1710
1711
1712
1713
1714
1715
1716
1717
1718
1719
1720
1721
1722
1723
1724
1725
1726
1727
1728
1729
1730
1731
1732
1733
1734
1735
1736
1737
1738
1739
1740
1741
1742
1743
1744
1745
1746
1747
1748
1749
1750
1751
1752
1753
1754
1755
1756
1757
1758
1759
1760
1761
1762
1763
1764
1765
1766
1767
1768
1769
1770
1771
1772
1773
1774
1775
1776
1777
1778
1779
1780
1781
1782
1783
1784
1785
1786
1787
1788
1789
1790
1791
1792
1793
1794
1795
1796
1797
1798
1799
1800
1801
1802
1803
1804
1805
1806
1807
1808
1809
1810
1811
1812
1813
1814
1815
1816
1817
1818
1819
1820
1821
1822
1823
1824
1825
1826
1827
1828
1829
1830
1831
1832
1833
1834
1835
1836
1837
1838
1839
1840
1841
1842
1843
1844
1845
1846
1847
1848
1849
1850
1851
1852
1853
1854
1855
1856
1857
1858
1859
1860
1861
1862
1863
1864
1865
1866
1867
1868
1869
1870
1871
1872
1873
1874
1875
1876
1877
1878
1879
1880
1881
1882
1883
1884
1885
1886
1887
1888
1889
1890
1891
1892
1893
1894
1895
1896
1897
1898
1899
1900
1901
1902
1903
1904
1905
1906
1907
1908
1909
1910
1911
1912
1913
1914
1915
1916
1917
1918
1919
1920
1921
1922
1923
1924
1925
1926
1927
1928
1929
1930
1931
1932
1933
1934
1935
1936
1937
1938
1939
1940
1941
1942
1943
1944
1945
1946
1947
1948
1949
1950
1951
1952
1953
1954
1955
1956
1957
1958
1959
1960
1961
1962
1963
1964
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
2034
2035
2036
2037
2038
2039
2040
2041
2042
2043
2044
2045
2046
2047
2048
2049
2050
2051
2052
2053
2054
2055
2056
2057
2058
2059
2060
2061
2062
2063
2064
2065
2066
2067
2068
2069
2070
2071
2072
2073
2074
2075
2076
2077
2078
2079
2080
2081
2082
2083
2084
2085
2086
2087
2088
2089
2090
2091
2092
2093
2094
2095
2096
2097
2098
2099
2100
2101
2102
2103
2104
2105
2106
2107
2108
2109
2110
2111
2112
2113
2114
2115
2116
2117
2118
2119
2120
2121
2122
2123
2124
2125
2126
2127
2128
2129
2130
2131
2132
2133
2134
2135
2136
2137
2138
2139
2140
2141
2142
2143
2144
2145
2146
2147
2148
2149
2150
2151
2152
2153
2154
2155
2156
2157
2158
2159
2160
2161
2162
2163
2164
2165
2166
2167
2168
2169
2170
2171
2172
2173
2174
2175
2176
2177
2178
2179
2180
2181
2182
2183
2184
2185
2186
2187
2188
2189
2190
2191
2192
2193
2194
2195
2196
2197
2198
2199
2200
2201
2202
2203
2204
2205
2206
2207
2208
2209
2210
2211
2212
2213
2214

the wafer can be positively held on the substrate holder at its peripheral edge and hence the wafer can be positively maintained in the vertical or inclined condition. Thus, the wafer can be prevented from falling down or dropping from the substrate holder. Further, even if the wafer is rotated by the rotating means, the external force such as the force of gravity acting on the wafer can be prevented by the clamping forces from the clamping members thereby preventing the wafer from coming off and dropping from the substrate holder as well as the movement of the wafer. Thus, it is possible to avoid the occurrence of crystal defects due to the shock by the dropping or collision and thereby to produce the high-quality semiconductor wafer. Further, even if the wafer is thermally deformed, the substrate holder and the wafer can be positively held in close contact by the clamping forces thereby maintaining the holding condition.

As for example, such clamping members can be provided by forming resilient members of such material as thin quartz or SiC into arcuate shape so as to clamp the wafer and the substrate holder by the ends of the respective resilient members.

According to still another preferred embodiment of the present invention, the substrate holder includes a peripheral edge contact portion for contacting at least the back surface side of the peripheral edge of the mounted wafer, and holding members adapted to contact with the peripheral edge of the mounted wafer and exert a holding force of such degree that the wafer is prevented from coming off even if it is rotated while being held vertically or obliquely at the desired position within the heat treatment apparatus, and the holding members include clamping members adapted for contacting with the principal surface side of the peripheral edge of the mounted wafer and for clamping and holding the wafer between the same and the peripheral edge contact portion.

In this embodiment, when the substrate holder is installed vertically or obliquely, the falling down or dropping of the wafer is prevented by the clamping members. Also, even though the wafer is rotated, the occurrence of crystal

defects due to the dropping or movement of the wafer can be prevented.

Thus, this embodiment has the effect that since the substrate holder includes the holding members which are adapted to contact the peripheral edge of the wafer mounted on the holder and exert a holding force of such degree that the wafer is prevented from coming off even though it is rotated by the rotating means, the holding of the semiconductor wafer on the substrate holder is made positive and the occurrence of crystal defects due to the falling down or dropping of the wafer in the course of heat treatment is prevented thereby producing the high-quality semiconductor wafer.

Further, this embodiment has the effect that even if the heat treatment is performed while rotating the semiconductor wafer held in position vertically or obliquely, the occurrence of collision with any other member due to the movement of the wafer or the dropping thereof can be prevented thereby producing the high-quality semiconductor wafer.

The above and other features and advantages of the present invention will be understood more clearly from the following description of the preferred embodiments referring in conjunction with the accompanying drawings which are shown for illustrative purposes only without any intention to limit the scope of the invention.

Brief Description of Drawings

Fig. 1 is a perspective view showing schematically the construction of a wafer holding device according to an embodiment of the present invention.

Fig. 2 is a diagram in vertical sectional view showing schematically the construction of an epitaxial growth furnace equipped with the wafer holding device shown in Fig. 1.

Fig. 3 is a partial sectional view showing schematically, with the omission of the hatching, the construction of a wafer holding device according to another embodiment of the present invention.

Fig. 4 is a diagram in vertical sectional view showing schematically the construction of a vertical-type epitaxial growth furnace equipped with a wafer holding device according to still another embodiment of the present invention.

Fig. 5 is an enlarged front view of a susceptor, contact members and resilient members according to an embodiment of the present invention.

Fig. 6 is a diagram in vertical sectional view showing schematically the construction of a vertical-type epitaxial growth furnace equipped with a wafer holding device according to still another embodiment of the present invention.

Fig. 7 is an enlarged front view of a susceptor and resilient members according to still another embodiment of the present invention.

Fig. 8 is a partial enlarged sectional view of a susceptor and resilient members according to still another embodiment of the present invention.

Best Mode for Carrying Out the Invention

A first embodiment consists in an epitaxial growth furnace equipped with a wafer holding device according to the present invention. The epitaxial growth furnace of the first embodiment is a horizontal-type epitaxial growth furnace for growing an epitaxial film on the surface of a semiconductor wafer while holding the wafer in a horizontal position, and its schematic construction is shown by the sectional view of Fig. 2. As shown in Fig. 2, the horizontal-type epitaxial growth furnace 201 of this embodiment includes a reaction chamber 2, a wafer holding device 206 for holding a semiconductor wafer W within the chamber, a reaction gas injector port 15 for supplying a reaction gas into the chamber, a reaction gas vent port 17 for the suction exhaust of the gas within the chamber, and infrared lamps 13 for heating the chamber interior to the desired temperature. The wafer holding device 206 of this embodiment utilizes a quartz plate for its resilient mechanism. As shown in Fig. 2, the wafer holding device 206 includes a susceptor 207 mounted within the chamber 2 and a quartz plate 204 coaxially disposed on the lower surface of the susceptor 207. As shown in Fig. 1, a

plurality of support pins 205 are disposed on the upper surface of the quartz plate 204 to protrude therefrom. On the other hand, the susceptor 207 is formed with holes 203 therethrough so as to coincide with the arrangement of the support pins 205. The support pins 205 are respectively inserted into the corresponding holes 203 so that the forward ends of the pins 205 project from the surface of the susceptor 207.

In order to support the wafer W along the four orientations lying on the wafer back surface side and respectively designated as E, F, G and H in Table 1, four units of the support pins 205 are protruded from the surface of the susceptor on three concentric circles in the wafer holding area at regular angular intervals of 90-degrees. In this embodiment, every four of the pins are arranged on each of three concentric circles. Therefore, every three of the pins are arranged on each of the radii corresponding to the previously mentioned four orientations, thus arranging the twelve support pins 205 in total.

When mounting the wafer W on these support pins 205, usually use is made of a marking e.g., an orientation notch N formed at the position corresponding to the 110 orientation. More specifically, the wafer W is mounted in such a manner that the direction of the straight line connecting the notch N and the center of the wafer W is brought into registration with one of the four rows of the radially arranged support pins 205 and the center of the wafer W is made coaxial with the susceptor 207. When the wafer is mounted in this way, the four rows of support pins 205 respectively support the wafer W along the four orientations on the back surface of the wafer W.

It is to be noted that the support pins 205 are protrusively disposed on the quartz plate 204 having flexibility even a bit so that the load or weight acting on the support pins 205 is dispersed until the loading action and the reaction of the supporting side are balanced by the elasticity of the quartz plate 204. As a result, when the wafer W is mounted on the support pins 205, the wafer W is eventually supported uniformly by all the support pins 205.

With the epitaxial growth furnace 201 equipped with the wafer holding device 206 constructed as described hereinabove, the epitaxial growth process is performed in the following manner.

The wafer W which has been preliminarily subjected to the desired processes including the removal of surface oxide film and polishing, is transferred to the loading position of the susceptor 207 within the chamber 2 by a robot arm (not shown). At this time, as mentioned previously, the wafer W is loaded on the susceptor 207 such that while aligning the direction of the notch N of the wafer W with one of the four rows of the support pins 205, the supporting positions by the four rows of support pins 205 are respectively brought into coincidence with the four orientations E, F, G and H on the wafer back surface.

Then, the interior of the chamber 2 is closed and heated up to about 1100 °C to 1200 °C by the infrared lamps 13.

Thereafter, a reaction gas e.g., SiCl_4 , SiHCl_3 , SiH_2Cl_2 , SiH_4 or the like is introduced from the reaction gas injector port 15. At this time, as the result of the thermal decomposition or reducing action of the reaction gas, an epitaxial film is grown on the principal surface of the wafer W thereby producing an epitaxial wafer.

During the performance of the epitaxial growth process of the present embodiment, the wafer W is supported uniformly by the large number of support pins 205, and more especially the wafer is supported stably at those locations where the mechanical strength of the wafer is highest from the physical property point of view. Thus, as compared with the conventional cases of supporting at three points only, the local loading at the respective supporting points is reduced and the stress applied to the wafer W is decreased considerably. Therefore, the danger of causing a slip defect due to the stress is also decreased greatly.

An epitaxial growth furnace using a wafer holding device according to a second embodiment will now be explained. This wafer holding device includes resilient mechanisms which are different from that of the first embodiment and the

construction is shown by the partial sectional view of Fig. 3. It is to be noted that the second embodiment is the same with the first embodiment except the wafer holding device so that only the construction of the wafer holding device is shown and the explanation of the remainder is omitted. In the second embodiment, spherical support pins 223, each of which is formed by a ball, are arranged on the surface of a susceptor 220 and it is assumed that these support pins are arranged in the same manner as the support pins of the first embodiment.

The wafer holding device of the second embodiment includes a resilient mechanism at the position of each of the spherical support pins 223 in the susceptor 220. More specifically, as shown in Fig. 3, formed at the desired positions of arrangement of the support pins on the surface of the susceptor 220 are a plurality of blind holes 221 which are stair-shaped in section. A leaf spring 222 made from quartz is fitted on the stairs of the inner wall of each hole 221 so as to close it. An opening is provided in the center of each leaf spring 222 and the spherical support pin 223 is disposed in the opening in a manner that its lower part is fitted therein. As a result of this construction, the spherical support pins 223 are respectively supported by the flexible leaf springs 222.

Also, the upper ends of the spherical support pins 223 are slightly projected from the surface of the susceptor 220 thereby supporting the wafer W through the point contact therewith. When the wafer W is loaded on such susceptor 220, the wafer W is supported uniformly by virtue of the elasticity of the leaf springs 222 of all the spherical support pins 223.

Further, as in the case of the first embodiment, by placing the supporting positions of the spherical support pins 223 in coincidence with the four orientations E, F, G and H, respectively, on the wafer back surface, the wafer W is supported stably at the locations where the mechanical strength is highest.

With the epitaxial growth furnace equipped with such holding device, the local loading at the supporting points of the respective spherical support pins 223 is also reduced and the stress caused in the wafer during the performance of the

epitaxial growth process is also reduced, thereby decreasing the danger of the occurrence of a slip.

It is to be noted that while, in the embodiments described above, the total of twelve (12) support pins, three (3) pins each, are respectively arranged along the four radial directions, it is of course possible to arrange the decreased or increased number of support pins. Particularly, where it is desired to hold a wafer having much weight e.g., a large-diameter wafer of more than 400 mm in diameter, it is desirable to uniformly support the wafer with a greater number of support pins, and moreover it is desirable to use as a basis a support pin arrangement which supports along the crystal orientations $\langle 110 \rangle$.

An epitaxial growth furnace according to a third embodiment will now be described. The epitaxial growth furnace of the third embodiment is used for growing an epitaxial film on the principal surface of a semiconductor wafer while holding the wafer vertically and its schematic construction is shown in Fig. 4. As shown in the figure, the epitaxial growth furnace 1 of this embodiment includes a reaction chamber 2, a susceptor 3 serving as a substrate holder for holding a semiconductor wafer W within the chamber 2, a holder 9 for holding the susceptor 3 in place, rotary drive means 11 for rotating the susceptor 3 with the wafer W held thereon, a reaction gas injector port 15 for supplying a reaction gas, a reaction gas vent port 17 for the suction exhaust of the gas within the chamber, and infrared lamps 13 for heating the chamber interior to the desired temperature.

The susceptor 3 is vertically mounted on the susceptor holder 9 within the chamber and it is rotatable in the circumferential direction of the susceptor by the rotary drive means 11. A recess is formed in the surface of the susceptor 3 and the wafer W is received in the recess 4. Fig. 5 illustrates an enlarged front view showing the manner in which the wafer is received in the recess 4 of the susceptor 3 of this embodiment. As shown in Fig. 5, four resilient members 7 and 8 made from thin quartz or SiC material are mounted on the inner wall of the recess 4 of the susceptor 3 at 90-deg intervals with respect to the central angle

of the wafer. Of these, each of the three resilient members 7 is of a compressed type spring composed of stacked thin plates. The remaining resilient member 8 has an arcuate shape and its elastic force is produced by its expansion and contraction in the radial direction. A contact member 5 of carbon SiC-CVD coated type or made from SiC or quartz is fitted on the forward end of the compressed springs 7 and the arcuate spring 8, respectively. The contact members 5 support the peripheral edge of the wafer set in the recess 4. More specifically, the wafer W set in the recess 4 is supported at its peripheral edge by the contact members 5 which are energized from the outside of the peripheral edge toward the center of the wafer by the spring force of the four springs, that is, the compressed springs 7 and the arcuate spring 8. It is to be noted that while, in this embodiment, the compressed springs 7 and the arcuate spring 8 are used in combination, it is needless to say that use can be made of such construction in which all the resilient members are composed of the arcuate springs 8 or all the resilient members are composed of the compressed springs 7 as well.

Now, the method of growing an epitaxial film on the wafer surface by utilizing the epitaxial growth furnace 1 constructed as above mentioned will be explained.

The semiconductor wafer which has been preliminarily subjected to the processes including the removing of surface oxide film, polishing etc., is first transferred to the mounting position of the susceptor 3 in the chamber 2 and it is then set in the recess 4 of the susceptor 3.

At this time, the peripheral edge of the wafer W is supported by the four contact members 5. The wafer W which has been set in the recess 4 and supported at its peripheral edge by the four contact members 5, is energized from the outside of the peripheral edge toward the center by virtue of the spring force of the compressed springs 7 and the arcuate spring 8.

As a result, the wafer W held in a vertical manner is positively held in the recess 4 of the susceptor 3 due to the support by the contact members 5 and the

energization toward the center provided by the springs 7 and 8, thereby preventing the falling down or dropping of the wafer from the susceptor 3.

Thereafter, the interior of the chamber 2 is closed and the interior of the chamber is heated up to about 1100 °C to 1200 °C by the infrared lamps 13. At the same time, the wafer W is rotated, along with the susceptor 3, in the circumferential direction by the rotary drive means 11. At this time, the peripheral edge of the wafer W is supported by the contact members 5 and the contact members 5 are energized from the outside of the peripheral edge toward the center by the springs 7 and 8, with the result that the external force such as the force of gravity acting on the wafer during the rotation is absorbed by the spring force of the springs 7 and 8. As a result, the movement of the wafer W within the recess 4 is prevented by the springs 7 and 8. In other words, there is the effect that the wafer is prevented from moving within the recess 4 and colliding with the inner wall or dropping from the susceptor 3 during its rotation.

Then, a reaction gas e.g., SiCl_4 , SiHCl_3 , SiH_2Cl_2 , SiH_4 or the like is introduced from the reaction gas injector port 15. At this time, an epitaxial film is grown on the principal surface of the wafer W due to the thermal decomposition or reducing action of the reaction gas, thereby producing an epitaxial wafer.

Next, an epitaxial growth furnace according to a fourth embodiment will be described. Fig. 6 illustrates a diagram in vertical sectional view showing the schematic construction of the epitaxial growth furnace 1 according to the fourth embodiment. The epitaxial growth furnace 1 of this embodiment is identical with that of the third embodiment except only the susceptor and the resilient members so that the common parts are designated by the same reference numerals and their explanation is omitted.

Fig. 7 illustrates an enlarged front view of the susceptor 3 in the fourth embodiment. The susceptor 3 includes the recess 4 for receiving a semiconductor wafer and the inner wall of the recess 4 is formed so as to internally contact with the peripheral edge of the wafer. Also, as shown in Fig. 7,

the susceptor 3 is divided into eight sector supporting portions 6 which are constructed so as to be movable in the radial direction of the semiconductor wafer.

The springs 7 made from thin quartz or SiC thin plates are mounted, one for each sector supporting portion, between the outer wall of the susceptor 3 or the peripheral edge portions of the sector supporting portions 6 and the susceptor holder 9. Thus, the wafer W set in the recess 4 is supported at its peripheral edge by the stepped portions of the sector supporting portions 6 or the inner wall of the recess 4, and the sector supporting portions 6 are respectively energized from the outside of the peripheral edges toward the center by the spring force of the springs 7.

As a result, the wafer W held vertically within the chamber 2 is firmly held in the recess 4 owing to the support by the stepped portions of the sector supporting portions 6 (the inner wall of the recess 4) and the energization toward the center by the springs 7, thereby preventing the falling down or dropping of the wafer. Also, when the wafer is rotated in the circumferential direction, the external force such as the force of gravity acting on the wafer during the rotation is absorbed by the spring force of the springs 7. Thus, the movement of the wafer within the recess is prevented by the springs 7, thereby preventing the wafer from moving within the recess 4 and colliding against its inner wall or dropping from the susceptor 3 during the rotation.

Next, an epitaxial growth furnace according to a fifth embodiment will now be described. The epitaxial growth furnace 1 of this embodiment is identical with that of the third embodiment except the susceptor 3 so that the common parts are designated by the same reference numerals and their explanation is omitted. Fig. 8 is a partial enlarged sectional view showing schematically the construction of the susceptor 3 in the fifth embodiment. The susceptor 3 includes the recess 4 for receiving a semiconductor wafer. Mounted on the susceptor holder 9 are arcuate springs 8 which are made from thin quartz or SiC and arranged at

90-deg intervals with respect to the central angle of the wafer so as to respectively clamp and energize the corresponding peripheral portions of the wafer and the susceptor 3 toward the center with the wafer being received in the recess 4 of the susceptor 3. Due to the fact that the arcuate springs 8 clamp the peripheral portions of the wafer and the susceptor 3, the wafer is positively held on the susceptor 3, thus preventing the wafer from falling down or dropping. Also, even if the wafer W is rotated, the external force e.g., the force of gravity is absorbed by the arcuate springs 8 owing to the spring force thereof so that the wafer is prevented from moving within the recess 4 and colliding with its inner wall or dropping from the susceptor 3 during the rotation.

CLAIMS

We claim:

1. A wafer holding device adapted for use in an apparatus for treating a principal surface of a semiconductor wafer under a predetermined heating condition while the back surface of said principal surface of the wafer is held by the device at a predetermined position within a chamber of said apparatus, said device comprising :

a susceptor formed in the surface thereof with a wafer loading area for supporting the back surface of the wafer, and

a plurality of support pins each arranged at one of four equiangularly spaced positions along a circumference of at least one concentric circle in said wafer loading area so as to protrude from the surface of said susceptor, each of said support pins including a resilient mechanism.

2. The wafer holding device according to claim 1, wherein said support pins are disposed in the positions which support the wafer along the crystal orientation $\langle 110 \rangle$ with respect to the crystal plane (100) of the wafer.

3. The wafer holding device according to claim 1, wherein said resilient mechanism includes a plurality of flexible members each supporting one of said support pins.

4. The wafer holding device according to claim 3, wherein each said flexible member comprises a leaf spring made from quartz.

5. (Amended) A wafer holding device adapted for use in an apparatus for treating a principal surface of a semiconductor wafer under a predetermined heating condition while the back surface of said principal surface of the wafer is

vertically or obliquely held by the device at a predetermined position within a chamber of said apparatus, said device comprising:

a substrate holder for supporting the back surface of said wafer thereon,
rotating means for circumferentially rotating said wafer along with the substrate holder, and

a plurality of holding members provided on said substrate holder and placed in contact with the peripheral edge of said wafer loaded thereon, said holding members being adapted to act against said peripheral edge of said wafer to exert a holding force toward the center of said wafer in such degree that said wafer is prevented from coming off when said wafer is rotated along said substrate holder by said rotating means.

6. The wafer holding device according to claim 5, wherein said substrate holder includes an inner wall surface disposed to face the peripheral edge of said wafer loaded on said substrate holder, and wherein said holding means includes a plurality of contact members for contacting with the peripheral edge of said wafer and a plurality of energizing members disposed on said inner wall surface to apply an energizing force tending toward a center of said wafer to said contact members.

7. The wafer holding device according to claim 5, wherein said substrate holder includes an inner wall surface disposed to face the peripheral edge of said wafer loaded on said substrate holder, and wherein said holding means includes inner-wall contact means including a part or a whole of a plurality of sections forming said inner wall surface and energizing means for energizing said inner-wall contact means toward a center of said wafer.

8. (Amended) A wafer holding device adapted for use in an apparatus for treating a principal surface of a semiconductor wafer under a predetermined

heating condition while the back surface of said principal surface of the wafer is vertically or obliquely held by the device at a predetermined position within a chamber of said apparatus, said device comprising:

a substrate holder for supporting the back surface of said wafer thereon;
and

rotating means for circumferentially rotating said wafer along with the substrate holder,

said substrate holder including periphery contact means for contacting with at least a portion of the back surface at the peripheral edge of said wafer loaded on said substrate holder,

said holding means including clamping means for contacting with a portion of the principal surface at the peripheral edge of said wafer loaded on said substrate holder and for clamping and holding said wafer between the same and said periphery contact means.

ABSTRACT

A device for holding a semiconductor wafer, which is adapted for use in an apparatus for treating a semiconductor wafer under predetermined heating conditions while holding the wafer at a predetermined position within a chamber. The device comprises a susceptor formed in its surface with a wafer loading area for supporting a semiconductor wafer from its back side, and a plurality of support pins provided with a resilient mechanism and arranged at four equiangularly spaced positions on the circumference of at least one concentric circle in the wafer loading area so as to protrude from the surface of the susceptor to support the back surface of the wafer at the forward ends thereof. The support pins on the circle are positioned to support the wafer along the crystal orientation $\langle 110 \rangle$ with respect to the crystal plane (100) of the wafer.

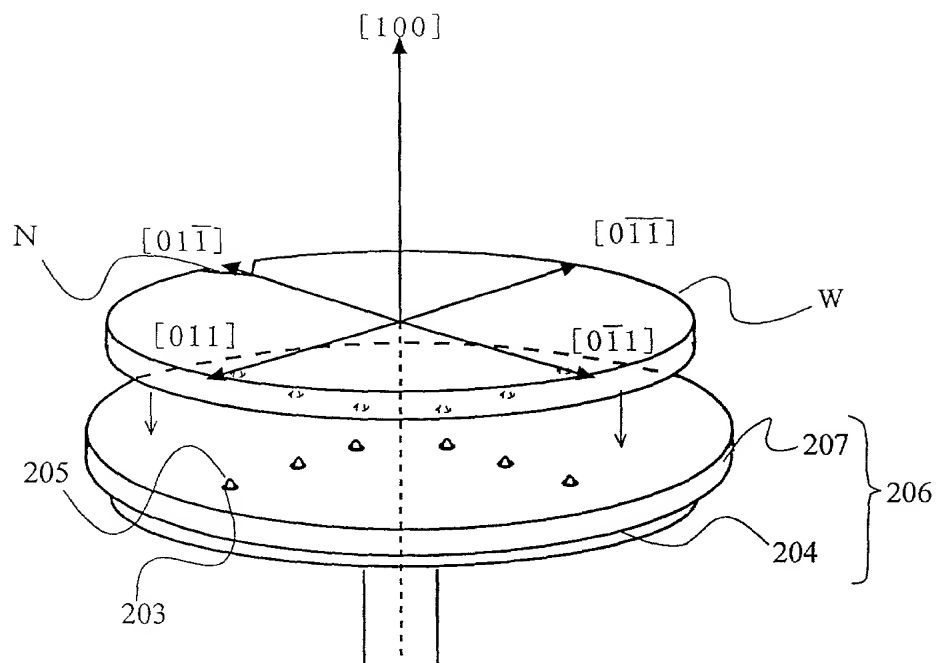


Fig.1

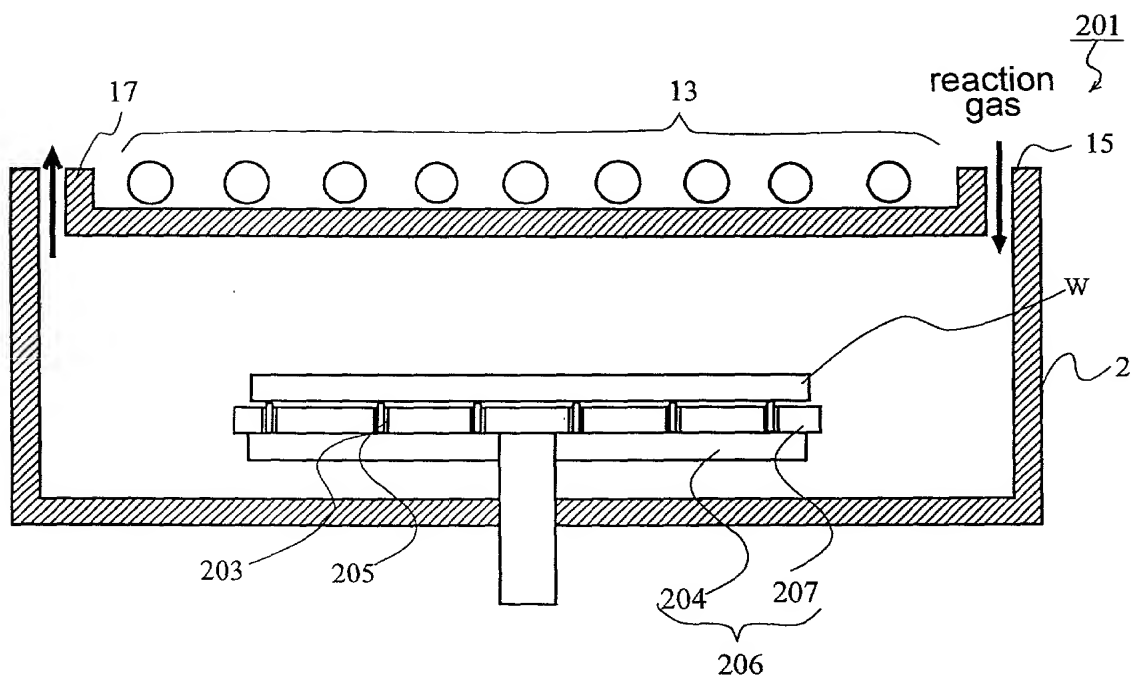


Fig.2

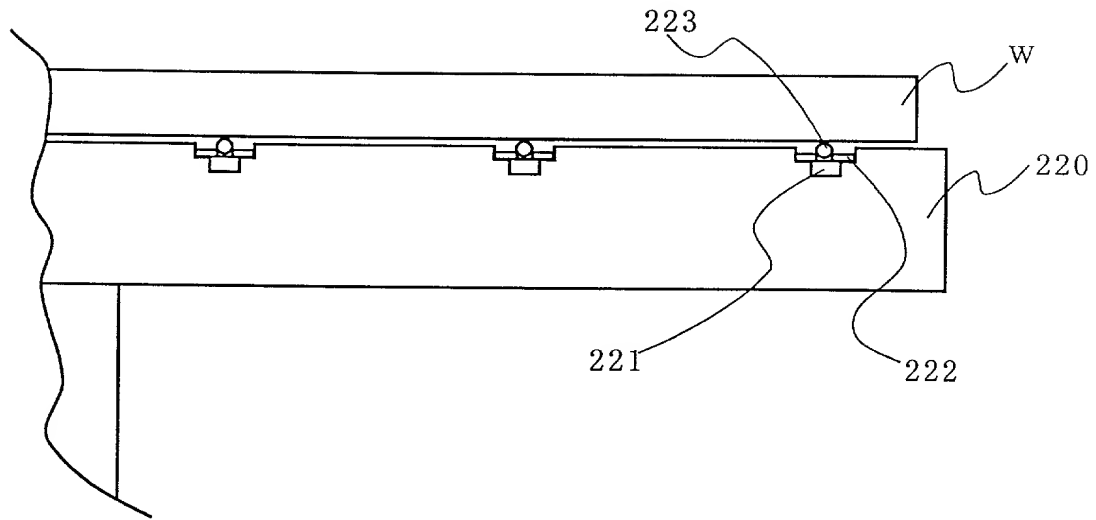


Fig.3

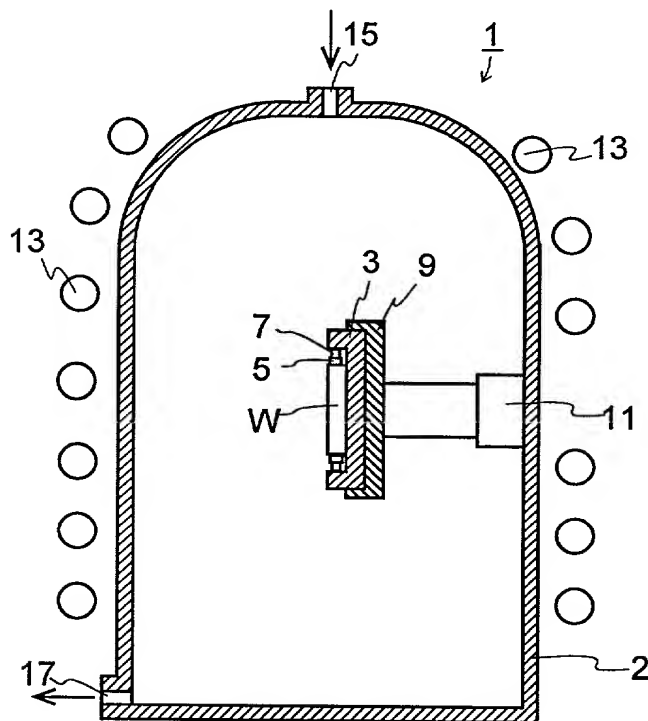


Fig.4

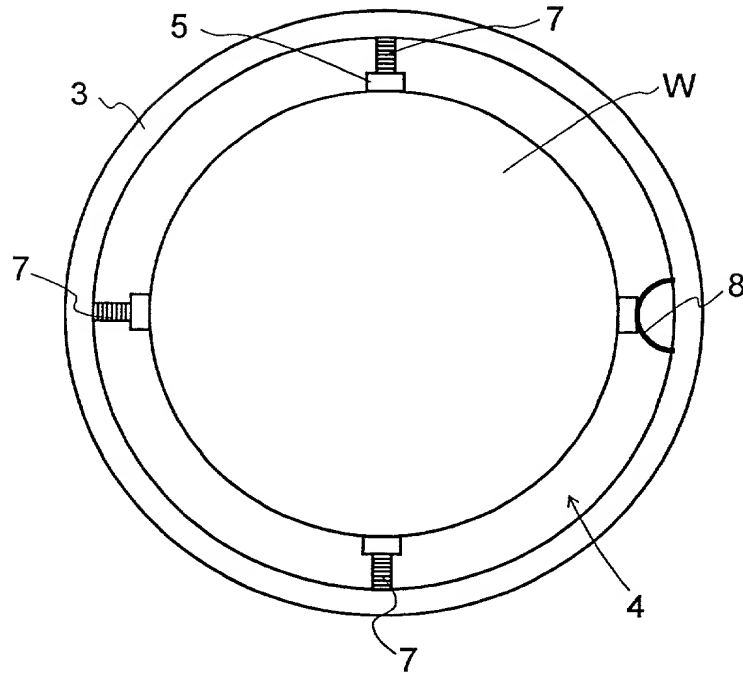


Fig.5

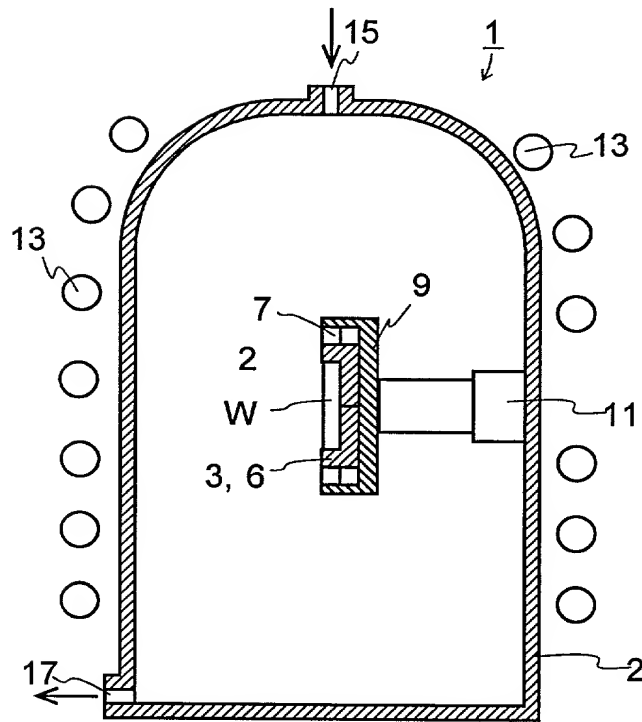


Fig.6

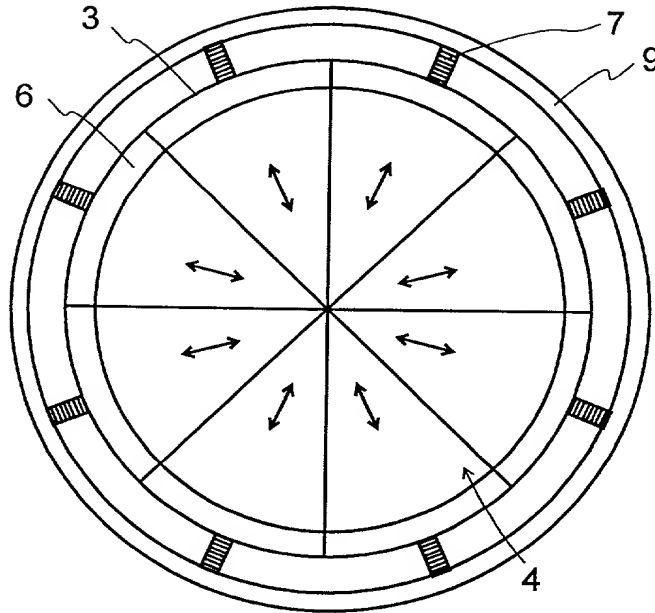


Fig.7

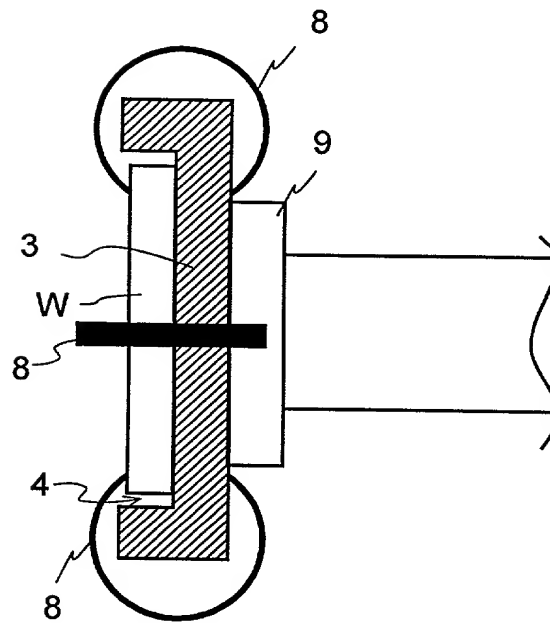


Fig.8

APPLICATION FOR UNITED STATES LETTERS PATENT
Post-Filed PCT Declaration and Power of Attorney (35 U.S.C. 371(c)(4))
PCT Application - United States Designated Office

As a below named inventor, I declare that:

My residence, post office address and citizenship are as stated below next to my name; I believe that I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled: **DEVICE FOR HOLDING SEMICONDUCTOR WAFER**

described and claimed in International Application number PCT/JP98/05212 filed November 19, 1998, and in U.S. Patent Application Serial No. 09/554,629, filed May 16, 2000.

I have reviewed and understand the contents of said specification, including claims.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR §1.56.

I claim priority benefits under 35 USC §119 of: (i) any foreign application(s) for patent or inventor's certificate listed below; or (ii) any United States provisional application(s) listed below; and have also identified below any foreign application(s) for patent or inventor's certificate, or PCT international application having a filing date before that of the application(s) on which priority is claimed.

COUNTRY	APPLICATION NUMBER	DATE (day, month, year)	PRIORITY CLAIMED
JAPAN	9-333725	19 November 1997	yes <u>X</u> no _____
JAPAN	10-64532	27 February 1998	yes <u>X</u> no _____

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

I appoint the following attorneys to prosecute this application and to transact all business in the U.S. Patent & Trademark Office connected therewith: Leonard Holtz, Reg. No. 22,974; Herbert Goodman, Reg. No. 17,081; Thomas Langer, Reg. No. 27,264; Marshall J. Chick, Reg. No. 26,853; Richard S. Barth, Reg. No. 28,180; Douglas Holtz, Reg. No. 33,902; and Robert P. Michal, Reg. No. 35,614.

CORRESPONDENCE AND CALLS TO:

FRISHAUF, HOLTZ, GOODMAN, LANGER & CHICK, P.C.
767 Third Avenue - 25th Floor Tel.: (212) 319-4900
New York, New York 10017-2023 Fax.: (212) 319-5101

INVENTOR: SIGNATURE**DATE****RESIDENCE AND POST OFFICE ADDRESS**

Sign: <u>Shinji Nakahara</u>	Date: <u>Oct. 6, 2000</u>	Residence: (City & Country) Gumma, JAPAN
Type: <u>Shinji NAKAHARA</u>	Citizen of: JAPAN	Post Office Address: 1412-2, Iizuka-machi, Takasaki-shi, <u>Gumma</u> , 370-0069, JAPAN
Sign: <u>Masato Imai</u>	Date: <u>26/5/2000</u>	Residence: (City & Country) Gumma, JAPAN
Type: <u>Masato IMAI</u>	Citizen of: JAPAN	Post Office Address: Casa Verde 11-204, 22-55, Annaka 3-chome, Annaka-shi, <u>Gumma</u> , 379-0116 JAPAN
Sign: <u>Masanori Mayasumi</u>	Date: <u>26/5/2000</u>	Residence: (City & Country) Gumma, JAPAN
Type: <u>Masanori MAYUSUMI</u>	Citizen of: JAPAN	Post Office Address: 12-37, Isobe 3-chome, Annaka-shi, <u>Gumma</u> 379-0127 JAPAN

APPLICATION FOR UNITED STATES LETTERS PATENT

Declaration and Power of Attorney

INVENTOR: SIGNATURE		DATE	RESIDENCE AND POST OFFICE ADDRESS
Sign: 	Date: 26 / 5 / 2000	Residence (City & Country): Gumma, JAPAN	
Type: Kazutoshi INOUE	Citizen of: Japan	Post Office Address: Bunkyo Heights 203, 36-18, Bunkyo-cho 1-chome, Maebashi-shi, Gumma, 371-0801, JAPAN	
Sign:	Date:	Residence (City & Country):	
Type:	Citizen of:	Post Office Address:	
Sign:	Date:	Residence (City & Country):	
Type:	Citizen of:	Post Office Address:	
Sign:	Date:	Residence (City & Country):	
Type:	Citizen of:	Post Office Address:	
Sign:	Date:	Residence (City & Country):	
Type:	Citizen of:	Post Office Address:	
Sign:	Date:	Residence (City & Country):	
Type:	Citizen of:	Post Office Address:	
Sign:	Date:	Residence (City & Country):	
Type:	Citizen of:	Post Office Address:	
Sign:	Date:	Residence (City & Country):	
Type:	Citizen of:	Post Office Address:	